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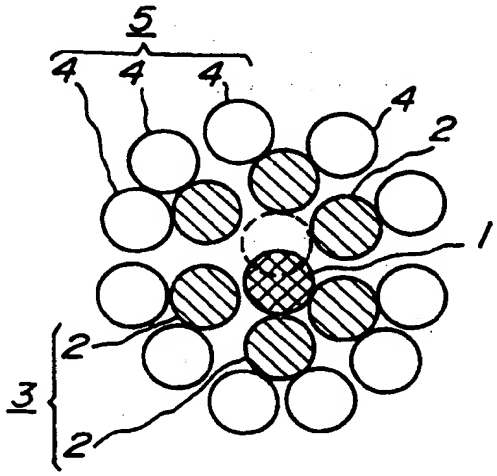
(54) Steel cords for the reinforcement of rubber articles and heavy duty pneumatic radial tires using the same.

(57) A rubber article-reinforcing steel cord includes a core (1) obtained by forming a single filament in a wavy shape, an inner sheath (3) formed by arranging 5 to 6 filaments (2) around the core, and an outer sheath (5) formed by arranging 9 to 12 filaments (4) around the inner sheath. The inner sheath (3) and said outer sheath (5) are twisted together. The diameter of each of the filaments of the inner and outer sheaths is not greater than that of the filaments of the core, $5d \leqq L \leqq 30d$ and $1.2 \leqq H \leqq 2.0d$ in which L and H are wave length and wave height of a wave shape of the waved filament of the core, respectively, and d is the diameter of the filament of the core, and a ratio p_3/p_2 between the twisting pitch p_2 of the inner sheath (3) and the twisting pitch P_3 of the outer sheath (5) is in a range of 1.4 to 2.5. A heavy duty pneumatic radial tire is also disclosed, which uses such steel cords in the belt thereof.

FIG_1



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The present invention relates to steel cords to be used as a reinforcement for rubber articles, for example, pneumatic tires to be used in heavy duty vehicles such as trucks or buses and industrial belts. In particular, the present invention is to improve fatigue resistance and corrosion propagation resistance of steel cords required for heavy duty tires.

A variety of properties have been required for steel cords to be used in, for example, heavy duty pneumatic tires. Among those properties, adhesion property to rubber is an important property, because the adhesion property affords large effects upon fatigue resistance and corrosion resistance. Regarding improvement upon the adhesion property to rubber, Japanese Utility Model registration publication No. 56-14,396 describes that when a core wire is helically formed and a plurality of peripheral filaments are twisted around the outer periphery of the core wire in the state that a plurality of these peripheral filaments do not contact one another, the adhesion property to rubber can be improved together with improvement on corrosion resistance of the steel cord itself through penetrating the rubber up to the interior of the cord.

However, in the case of a two-layer twisted structure having a construction of 3 + 6 illustrated in Japanese Utility Model registration publication No. 56-14,396, the diameter of the filaments needs be made greater so as to increase strength of the filaments, which is disadvantageous from the standpoint of fatigue resistance and makes it difficult to penetrate rubber in the interior of the three filament-twisted core wire.

However, since the three-layer twisted steel cords having a construction of 3 + 9 + 15 have excellent fatigue resistance, such three-layer twisted cords have been used as reinforcement for heavy duty tires. However, this three-layer twisted steel cord has the problem in that if the diameters of the filaments constituting the cord are made substantially equal, the filaments of each layer contact adjacent ones so that the rubber is difficult to enter the interior of the cord to deteriorate corrosion resistance of the cord.

With the above problem in mind, Japanese patent application Laid-open No. 59-223,503 proposes a 4 + 9 + 14 construction in which gaps are retained among filaments by reducing the number of filaments in the intermediate layer and the outer layer from that corresponding to the closest packing structure. However, when the core filament is helically formed and a plurality of the peripheral filaments are twisted around the outer periphery of the core filament, there is the possibility that the filaments in the intermediate layer fall inside a circle defined by the helically formed core filament. As a result, the permeation of the rubber into the interior of the cord may be interrupted or the uniform pulling of the filaments in the intermediate layer and the outer layer is deteriorated, resulting in the deterioration in tenacity or fatigue resistance of the cord. In particular, it is difficult to penetrate rubber inside the four filament-twisted core wire. Further, if the number by which the filaments are reduced in the intermediate layer and the outer layer is small, penetrability of the rubber inside the cord is low. If the number of the filaments is further reduced, the tenacity of the cords is lowered to make the cords unsuitable as reinforcement for the tire.

The present invention is directed to the above three-layer twisted cord having excellent fatigue resistance, and is to provide a rubber-reinforcing steel cord in which durability is improved by penetrating rubber in the interior of the cord to a largely increased degree without lowering tenacity of the cord. The invention is also to provide a heavy duty radial tire in which such steel cords are used in a belt.

The present invention is directed to a rubber article-reinforcing steel cord comprising a core obtained by forming a single filament in a wavy shape, an inner sheath formed by arranging 5 to 6 filaments around the core, and an outer sheath formed by arranging 9 to 12 filaments around the inner sheath, said core, said inner sheath and said outer sheath being twisted together, wherein the diameter of each of the filaments of the inner and outer sheaths is not greater than that of the filaments of the core, $5d \leqq L \leqq 30d$ and $1.2d \leqq H \leqq 2.0d$ in which L and H are a wave length and a wave height of a wave shape of the waved filament of the core, respectively, and d is a diameter of the filament of the core, and a ratio p_3/p_2 between the twisting pitch p_2 of the inner sheath and the twisting pitch p_3 of the outer sheath is in a range of 1.4 to 2.5. The present invention is further directed to a heavy duty pneumatic radial tire comprising a carcass as a skeleton, and a belt arranged radially outwardly of said carcass, said carcass extending toroidally between a pair of bead portions, wherein said belt is comprised of steel cords.

In the present invention, it is preferable to use, as the filaments constituting the steel cord, steel filaments which have a chemical composition corresponding to that of a piano wire or a hard steel wire having a content of carbon of 0.70 to 0.85 wt% with less non-metallic inclusion and are drawn to a diameter of 0.12 to 0.35 mm. The reason why the content of carbon is limited to not less than 0.70 wt% is to increase tensile strength of the steel cord per unit weight so as to, for example, reduce the weight of the tire. The reason why the content of carbon is preferably limited to not more than 0.85 wt% is that if the carbon content is more than 0.85 wt%, fatigue resistance is deteriorated. The reason why the diameter of the filament is preferably limited to not less than 0.35 mm is that if the diameter is more than 0.35 mm, fatigue resistance of the cord decreases. On the other hand, the reason why the diameter of the filament is preferably not less than 0.12 mm is that enough strength to reinforce, for example, heavy duty pneumatic tires, is given to cords.

These and other objects, features and advantages of the invention will be apparent upon the reading of the following description of the invention when taken in conjunction with attached drawings, with the understanding that some modifications, variations and changes of the same could be made by the skilled person in the art to which the invention pertains without departing from the spirit of the invention or the scope of claims appended hereto.

For a better understanding of the invention, reference is made to the attached drawings, wherein:

Fig. 1 is a sectional view of a steel cord according to the present invention;

Figs. 2(a) and 2(b) are views for illustrating wave shapes guide to core filaments, respectively; and

Fig. 3 is a sectional view of a pneumatic tire to which the cords according to the present invention are applied.

In Fig. 1 is shown a sectional view of a steel cord according to the present invention. In this figure, a core 1 is made of a single filament, an inner sheath 3 is arranged around the outer periphery of the core 1, and an outer sheath 5 is arranged around the outer periphery of the inner sheath 3. The inner sheath 3 is constituted by six filaments 2, and the outer sheath is constituted by eleven filaments 4. As shown in Fig. 2(a) or 2(b), the core 1 is formed in a waved shape. It is indispensable for the wave shape of the core to satisfy $5d \leqq L \leqq 30d$ and $1.2\,d \leqq H \leqq 2.0d$ in which L, H and d are a wave length, a wave height and a diameter of the filament, respectively. The shape of the waves of the filament may be either of a climpto as a two-dimensional wave shape, such as a rectangular shape or a sinusoidal shape or of a helical shape as a three-dimensional wave shape.

The reason why the construction of the steel cord according to the present invention is limited to the three-layer twisting is to ensure good fatigue resistance. The reason why the inner and outer sheaths are constituted not by twisted wires but by the filaments is not only to improve productivity but also to avoid a phenomenon that when the sheath is constituted by the twisted wires, rubber is difficult to enter the Interior of the sheath, resulting in deterioration in corrosion resistance of the cord.

Next, the reason why the wave length L of the wave shape of the formed core and the diameter d of the filament constituting the core must satisfy the relationship: $5d \leqq L \leqq 30d$ is that if the wave length L exceeds 30d, side pressure resistance (resistance of the cord against pressure applied to the peripheral face of the cord) is decreased, with the result that gaps among the filaments of the cord, for example, during the production of the tire, decrease to make difficult the permeation of rubber into the interior of the cord. On the other hand, if the wave length L is less than 5d, wave-forming conditions for the core filament becomes severer to lower tensile strength of the filament of the core.

The reason why the wave height H of the wave shape of the formed core must satisfy the range of $1.2d \leqq H \leqq 2.0d$ is that if the wave height is less than 1.2d, the gaps among the filaments in the inner and outer sheaths become so small that the degree of permeating the rubber in the interior of the cord drops, whereas if the wave height H is more than 2.0d, the arrangement of the filaments in the inner and outer sheath become disturbed so that the gaps among the filaments become non-uniform with the result that no rubber penetrate through filaments depending upon locations.

In order to penetrate rubber between the inner and outer sheaths, it is indispensable that the twisting pitch p_2 of the inner sheath and the twisting pitch p_3 of the outer sheath satisfy the ratio p_3/p_2 being 1.4 to 2.5 to prevent the filaments of the outer sheath from entering between the filaments of the inner sheath. If the ratio p_3/p_2 does not fall in the range of 1.4 to 2.5, the uniform pulling of the filaments is deteriorated.

When the above steel cords are used in a belt of a heavy duty pneumatic radial tire, rubber well penetrates inside the cords. Accordingly, a phenomenon so called "cut separation" that peeling occurs at a bonded portion due to propagation of corrosion inside the cord can be prevented. Further, since the three-layer twisted construction is employed, the steel cords can be employed in the belt of the heavy duty pneumatic radial tire without increasing the diameter of the filaments. This is advantageous from the standpoint of the fatigue resistance. The content of carbon in the steel cord is preferably set at 0.80 to 0.85 wt%, because in this case, a sufficient distance can be assured between the buried cords, and fracture durability at end portions of the belt can be improved, when the strength (tenacity x end count of the cords) of the belt is made equal.

The twisting way may be either a buncher twisting or a tubular twisting. However, the tubular twisting by which the filaments of the cord themselves are not twisted is preferred from the standpoint of the fatigue resistance. The twisting direction of the inner sheath and the outer sheath may be either normal or reverse. Further, the wave shape afforded upon the core 1 may extend in either a climpto or helical shape in the same plane.

[Experiment]

Steel cords having a specification shown in Table 1 are applied to a truck-bus pneumatic radial tire as

shown in Fig. 3. That is, the tire shown in Fig. 3 had four belt layers 7 through 10 on a carcass 6, and the steel cords given in Table 1 were applied to the belt layers 8 and 9. In this manner, various tires were prepared for testing.

With respect to the thus obtained tires, corrosion propagation resistance and cut separation resistance of the steel cords were evaluated, and results are also given in Table 1. A formed amount of the core in Table 1 was determined by taking out a core filament from the steel cord after removal of the sheaths such that no permanent deformation might occur upon the core filament, observing the core filament by means of a magnifying lens and measuring the wave length L and the wave height H indicated in Fig. 2.

The corrosion propagating resistance was examined according to a cut end corrosion (CEC) process. That is, the surface of a rubberized steel cord cut out from the belt layer of the tire was coated with a silicone sealant, opposite ends of the steel cord each were cut off after drying to give a sample of a length of about 10 cm, one end of the cord was immersed in a 10% sodium hydroxide aqueous solution for 24 hours, the cord was taken out from the solution, and a length of the rubber peeling from the cord from said one end was measured.

The cut separation resistance was evaluated according to a corrosion propagation drum testing method. That is, each tire was bored with a drill at three locations on a peripheral portion of the tire from an inner face of the tire to reach second to third belts, water was sealingly filled in a tire tube, then the tire was assembled onto a rim, and the tire was run on a drum over a distance of 20,000 km. Thereafter, the tire was decomposed, and the cut separation resistance was evaluated by measuring a maximum length of peeling at a bonded portion due to rust of the cord in the second and third belts.

Table 1(a)

		Comparative Example 1	Comparative Example 2	Example 1	Example 2
Construction		3+9+15+1	4+9+14	1+6+11	1+6+11
Diameter of filament (mm) *		0.23/0.23/0.23/0.15	0.23/0.23/0.23	0.30/0.25/0.25	0.30/0.25/0.25
Twisting pitch (mm)		5/12/18/5.5	5/11/17	3.3/11/17	1.5/11/17
Twisting direction		s/s/z/s	s/s/z	-/s/z	-/s/z
Diameter of cord (mm)		1.41 **	1.48	1.35	1.35
Content of carbon (wt%)		0.72	0.72	0.82	0.82
Shape of core		straight	straight	climpto	climpto
Distance between cords in belt (mm)		0.78	0.71	0.84	0.84
Core-formed amount	L/d_1	-	-	11	5
	H/d_1	-	-	1.3	1.2
	P_3/P_2	1.5	1.35	1.55	1.55
Resistance to corrosion propagation (mm)		entire range	entire range	10~30	10~25
Cut separation resistance (mm)		400	200	30	20

* : Core diameter (d_1)/inner sheath diameter (d_2)/outer sheath diameter (d_3) or $d_1/d_2/d_3$/ diameter of spiral filament

** : Diameter of cord containing no spiral filament

Table 1(b)

		Example 3	Example 4	Example 5	Example 6
Construction		1+6+11	1+6+11	1+6+11	1+5+9
Diameter of filament (mm) *		0.30/0.25/0.25	0.30/0.25/0.25	0.30/0.25/0.25	0.30/0.28/0.28
Twisting pitch (mm)		9/8.5/17	3.3/11/17	3.3/11/17	3.3/11/17
Twisting direction		-/s/z	-/s/s	s/s/z	-/s/z
Diameter of cord (mm)		1.35	1.35	1.35	1.44
Content of carbon (wt%)		0.82	0.82	0.82	0.82
Shape of core		climpto	climpto	helical	climpto
Distance between cords in belt (mm)		0.84	0.84	0.84	0.78
Core-formed amount	L/d_1	30	11	11	11
	H/d_1	2	1.3	1.3	1.5
	P_3/P_2	2	1.55	1.55	1.55
Resistance to corrosion propagation (mm)		10~35	10~20	10~30	10~30
Cut separation resistance (mm)		35	20	30	35

* : Core diameter (d_1)/inner sheath diameter (d_2)/outer sheath diameter (d_3) or $d_1/d_2/d_3$/ diameter of spiral filament

As compared with Comparative Examples 1 and 2, Examples 1 through 6 falling in the scope of the present invention have far more excellent corrosion propagation resistance and cut separation resistance.

According to the present invention, the degree of penetrating the rubber in the interior of the cord can be remarkably increased without lowering the tenacity of the cord in the three-layer twisted cord, so that the rubber article-reinforcing steel cords having excellent fatigue resistance and corrosion propagation resistance can be obtained. Further, when the rubber article-reinforcing steel cords are used in the belt of the heavy duty pneumatic radial tire, cut separation resistance, belt end-fracture resistance, and resistance against fracture due to fatigue of the steel cord can be improved for the heavy duty pneumatic radial tire.

Claims

1. A rubber article-reinforcing steel cord comprising a core (1) obtained by forming a single filament in a wavy shape, an inner sheath (3) formed by arranging 5 to 6 filaments (2) around the core, and an outer sheath (5) formed by arranging 9 to 12 filaments (4) around the inner sheath, wherein the said core, said inner sheath and said outer sheath are twisted together, and wherein the diameter of each of the filaments of the inner and outer sheaths is not greater than that of the filament of the core; $5d \leqq L \leqq 30d$ and $1.2d \leqq H = 2.0d$ in which L and H are wave length and wave height of a wave shape of the waved filament of the core, respectively, and d is the diameter of the filament of the core; and a ratio p_3/p_2 between the twisting pitch p_2 of the inner sheath (3) and the twisting pitch p_3 of the outer sheath (5) is in a range of 1.4 to 2.5.

2. A rubber article-reinforcing steel cord as claimed in claim 1, characterized in that the filaments constituting the steel cord have a chemical composition of a piano wire or a hard steel wire having a content of carbon of 0.70 to 0.85 wt%, and have a diameter of 0.12 to 0.35 mm.

3. A rubber article-reinforcing steel cord as claimed in claim 2, characterized in that the content of carbon is 0.80 to 0.85 wt%.

4. A heavy duty pneumatic radial tire comprising a carcass (6), and a belt (7-10) arranged radially outwardly of said carcass, said carcass extending toroidally between a pair of bead portions, characterized in that at least one belt layer (8,9) of said belt is comprised of steel cords as claimed in any of claims 1 to 3.

FIG_1

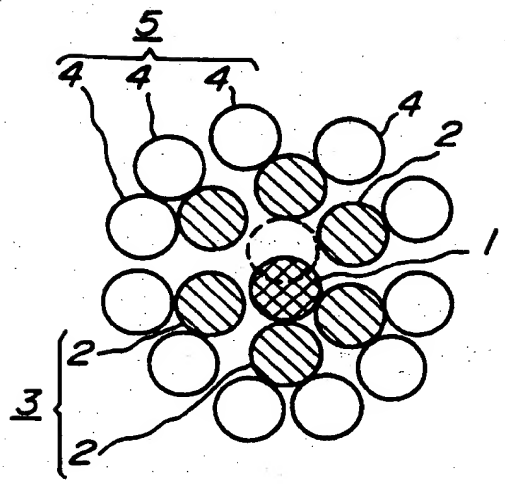


FIG_2a

FIG_2b

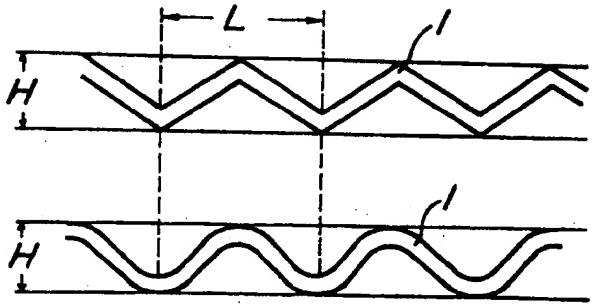
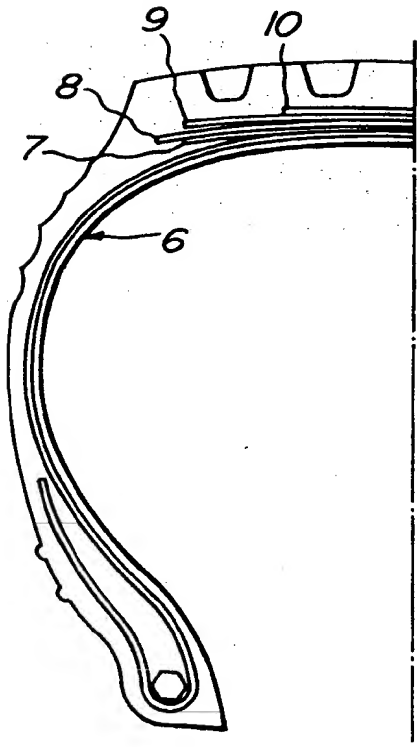


FIG_3



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EUROPEAN SEARCH REPORT

Application Number
EP 93 30 3144

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	RESEARCH DISCLOSURE no. 327, July 1991, EMSWORTH GB pages 552 - 558 327118 'Steel cord constructions made in one step' * introduction; examples illustrated in figures 3.7 and 5.1; conclusion *	1	D07B1/06
A		4	

A	RESEARCH DISCLOSURE no. 175, November 1978, EMSWORTH GB pages 26 - 27 17534 'Process for the manufacture of a strand, as well as a strand made according to this process, and elastomer or synthetic material objects reinforced wirh such strands' * the whole article *	1,4	

A	EP-A-0 176 139 (N.V. BEKAERT S.A.) * claims 1,2,4,7 * * page 11, line 12 - line 15 *	1-4	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
	-----		D07B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 JULY 1993	GOODALL C.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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